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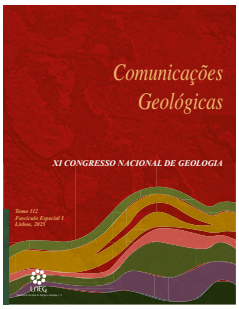
Patterns of sediment distribution on the Algarve leeward coast, Portugal

Padrões de distribuição sedimentar na costa sotavento Algarvia, Portugal



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Artigo original
Original article

Abstract: Sediment grain size gives important information on the origin and evolution of coastal sedimentary environments. This work reports the sediment grain size spatial distribution longshore and cross-shore the Southeastern Algarve coastal area, assessed through the analyses of 395 samples collected in 133 profiles, positioned along a 55 km continuous sector, from Ancão peninsula to Vila Real de Santo António.

The results are presented as the mean value of grain size and were clustered into the normalized classes of the Wentworth grain-size scale. The preliminary analysis reveals that the very fine and fine sand clusters are absent for the entire transect, even at the dune area, where the smallest average grain size is within the range of medium sand in the eastern sector and coarse sand at the western edge. General trends in the spatial distribution of sediments exhibit a distinctive variation resulting from the exposure to forcing agents along the study area.

Keywords: Grain size, Coastal dynamics, Barrier Islands, Algarve, Portugal

Resumo: A granulometria dos sedimentos fornece indicações importantes sobre a origem e evolução dos ambientes sedimentares da zona costeira.

Este trabalho apresenta a distribuição espacial da granulometria dos sedimentos no sotavento algarvio, resultante da análise de 395 amostras recolhidas em 133 perfis posicionados ao longo de uma faixa de 55 km, desde a península do Ancão até Vila Real de Santo António.

A análise preliminar dos resultados, apresentados em função do valor da média e agrupados nas classes normalizadas da escala de tamanho de grão (classificação de Wentworth), revela a ausência das classes granulométricas de areia muito fina e fina, mesmo na zona dunar, onde a classe de areia média domina no sector leste, e a de areia grosseira, no sector ocidental. O padrão geral de distribuição espacial da granulometria dos sedimentos exibe uma variação distinta ao longo da área de estudo, decorrente da exposição aos principais agentes forçadores.

Palavras-chave: Granulometria, Dinâmica costeira, Ilhas-barreira, Algarve, Portugal

1. Introduction

The need for increasing knowledge of the littoral dynamic processes has been progressively growing, in parallel with the reported evidence of the urgent requirement to adapt to climate change scenarios. Thus, a holistic approach to the understanding of coastal dynamics is crucial for an effective adaptive coastal governance, under the inevitable consequences on coastal zones.

Sediment characterization constitutes a useful tool to infer sediment sources and transport allowing a better understanding of coastal dynamics. This information is essential for efficacious planning and management of shore areas.

The eastern southern Portuguese coast, which is the focus of the current work, is a low-lying sandy shore that extends from Faro to the Guadiana River mouth, comprising a complex and highly dynamic barrier island system (Figura 1).

The evolutionary trend of the last decades points to a general seaward progradation at the western (Barreta island) and eastern (Cacela peninsula –VRSA) sectors, and an erosional trend at some sectors of the central barrier island system (Culatra, Tavira and Cabanas islands) (Nave and Rebêlo, 2021; Kombiadou *et al*., 2019; Lira *et al*., 2016). Interventions for shore protection and restoration of the eroded areas have been done during the last decades (Pinto *et al*., 2018), consequently, sediment deposition in the barrier island system has specific human interference related to activities of beach/dune renourishment.

This study was made within the "Geological and Coastal Hazard Mapping at a 1:3000 resolution scale" programme, developed by the Portuguese National Laboratory of Energy and Geology (Nave and Rebêlo, 2018).
https://geoportal.lneg.pt mapa/?escala=4000000&mapa=geologiacosteira#

2. Geological setting

The eastern southern Portuguese coast is a low-lying sandy shore extending over 50 km, from Faro to the Guadiana River mouth, comprising a complex and highly dynamic barrier island system (Figura 1). The barrier island system is composed of two peninsulas (Ancão and Cacela), the western and eastern limits of the system respectively, and five barrier islands, namely, from west to east, Barreta, Culatra, Armona, Tavira and Cabanas. The gateways for sedimentary, hydraulic, chemical, and nutrient transport between the ocean and the back barrier zone, are made through six tidal inlets (São Luís, Faro-Olhão, Armona, Fuseta, Tavira and Cacela inlets) (Figura 1).

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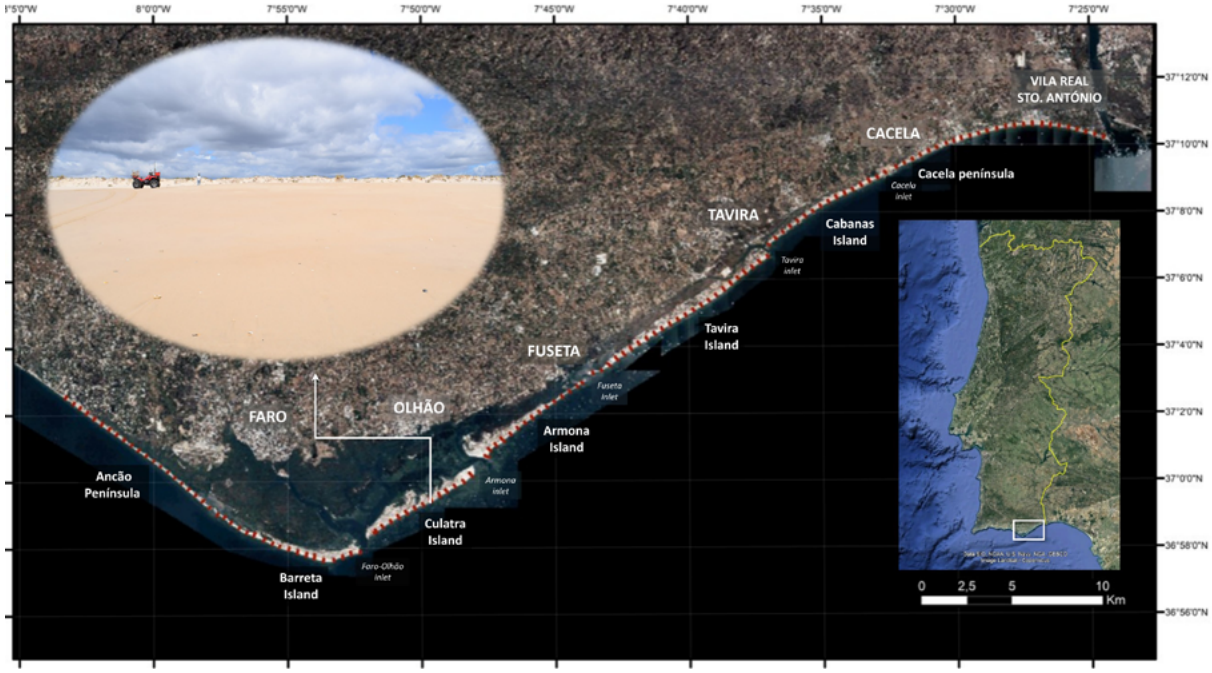

Figure 1. Study area and location of the 133 profiles, spaced approximately 500 m, and positioned between the Ancão Peninsula and the Guadiana River mouth.

Figura 1. Área de estudo e localizaçao dos 133 perfis posicionados entre a Península do Ancão e a Foz do Rio Guadiana, com espaçamento de, aproximadamente, 500 m.

The active phase of landward migration of the barrier islands is likely associated with a response to sea level rise, however, coastline evolution is related to many processes such as oceanic overwashes, longshore drift, dune building, tidal delta incorporation, inlet-associated processes and, with a negligible effect on the Ria Formosa barrier islands system, the erosion of back-barrier regions of the islands by spring tides (Dias 1988; Pilkey *et al*., 1989, Andrade, 1990). Besides these processes, anthropogenic activities generated relevant changes in coastal behaviour during the last decades, increasing process complexity and hampering the understanding of the natural coastal evolution (Ferreira *et al*., 2016; Kombiadou *et al*., 2019).

The morphodynamics in the Ria Formosa barrier island system varies according to the maritime agitation and tidal currents (Pilkey *et al*., 1989). The tides are semidiurnal mesotidal. The configuration and orientation of the coastal area, under study, provide two distinct sectors in terms of energy and exposure to wave action. The western flank is more energetic being under the direct influence of the dominant wave conditions, predominantly from the W-SW, while the eastern side is mostly exposed to moderate agitation of E-SE waves, generated by less intense local winds (Costa *et al.*, 2001). The predominant wave regime and the angular relationship of the waves with the shoreline orientation generates a net littoral drift, from west to east, forcing the position of the inlets to move in the same direction.

Previous studies revealed that sand fraction prevails at all depths of the inner shelf, reflecting the influence of littoral drift in the supply and redistribution of shelf sediments and suggesting that sedimentary pattern distribution is mainly associated with coastal processes (littoral drift and storm currents) and, in a lower degree, with sediment sources (Rosa *et al*., 2013). The observed relative homogeneity of the immersed central sector of the barrier islands is explained by the small contribution of continental sediments to the coastal zone, whilst large amounts of fines, deposited mainly in areas deeper than ca. 5m water depth off the Guadiana River mouth is directly related to river discharges (Rosa *et al*., 2013).

3. Material and methods

A total of 395 samples were collected in April 2019, during a 2 week-field operation where, besides samples and images, 133 beach profiles, spaced 500 meters, were measured between the Ancão peninsula and the Guadiana River mouth. In each profile, 3 samples were taken, at the dune-beach-surf zone system, for sedimentary characterization (Figura 2).

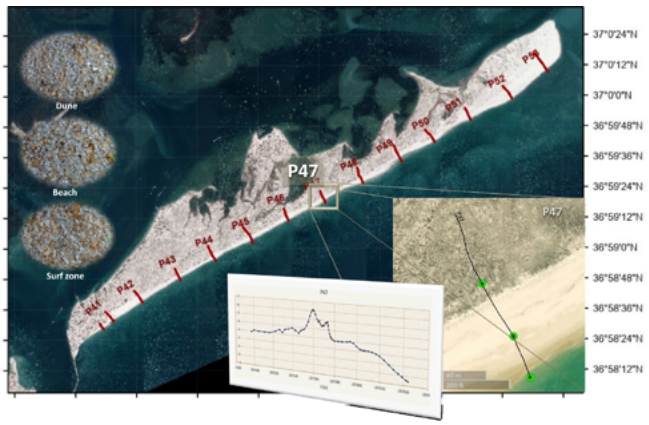

Figure 2. Example of the location of the samples collected at each profile (green dots), using as reference profile P47 positioned at Culatra island. Map produced using ArcGIS Pro, a software by Esri. Credits of base map from ArcGIS Pro: Maxar, Microsoft.

Figura 2. Exemplo de localização das amostras recolhidas em cada perfil (pontos verdes), utilizando como referência o perfil P47 posicionado na ilha da Culatra. Mapa produzido usando o software ArcGIS Pro da Esri. Créditos do mapa base do ArcGIS Pro: Maxar, Microsoft.

The grain size analysis was done at the Sedimentology Laboratory of LNEG, using the Coulter LS230 laser-sizer, whose repeatability is approximately ≤ 1% of the mean size (repeat runs of the same sample).

The results presented in the current work include the sample fraction < 2 mm, due to the limitation of the equipment used, whose capacity to determine particle size is limited to diameters between 0.04 and 2000 mm.

The original sample was divided using a sample splitter, and one half was set aside for archive and the other half for particle size analysis. The latter, after being weighed, was passed through the 2 mm sieve, and stored as sample fractions subsamples > 2 mm and < 2 mm. The < 2 mm fraction was then again split until a small sub-sample was obtained and analysed on Coulter Counter using the internal procedure PF5-LS: "Coulter LS230 Particle Analyser Sediment Analysis Procedure Guide".

About 65% of the samples do not have particles > 2 mm and 24% of the samples have 5% of grains > 2mm. Samples with particles > 2mm were mainly collected at the surf zone.

For each sample, 3 runs were performed. In case differences between the three runs were observed, the analysis was then repeated. The average values of grain-size data were then clustered into the normalized classes of the Wentworth classification grain-size scale (Wentworth, 1922).

4. Results

The minimum grain size mean value for the analysed fraction of the total amount of samples is 252 mm, and the maximum value is 1344 mm, leading to a class range between medium sand and very coarse sand. Thus, the grain-size mean values clustered into the normalized classes of very fine and fine sand are absent for the entire extension of the studied area.

The sorting parameter (determined by the method of moments), varies between 0,27 and 0,72, indicating that most of the analysed samples stand between very well-sorted and moderately well-sorted (Blott and Pye, 2001) (Figura 3).

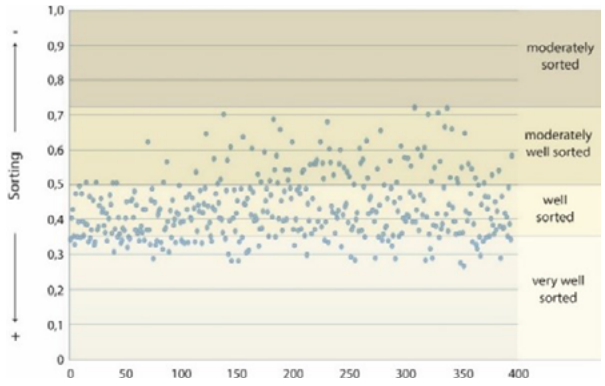

Figure 3. Sorting classification of the 395 analysed samples. Vertical axis: Sorting, Horizontal axis: number of the samples.

Figura 3. Classificação de calibração das 395 amostras analisadas. Eixo vertical: Calibragem, Eixo horizontal: número de amostras.

Patterns of grain size variation, for each environment (dune, beach, and surf zone), from Ancão Peninsula to the Guadiana River mouth were depicted.

At the surf zone, coarse to very coarse sand dominates, except at the Guadiana River mouth and Cabanas Island where medium sand is present (Figura 4). At the beach area, coarse sand dominates in the western sector, with medium sand extending at the eastern side, except at a few sectors where sand is very coarse (Figura 5).

The very fine and fine sand clusters are absent for the entire transect, even at the dune area which is characterized mainly by medium sand eastwards of Cape Santa Maria and coarse sand westwards of it (Figura 6).

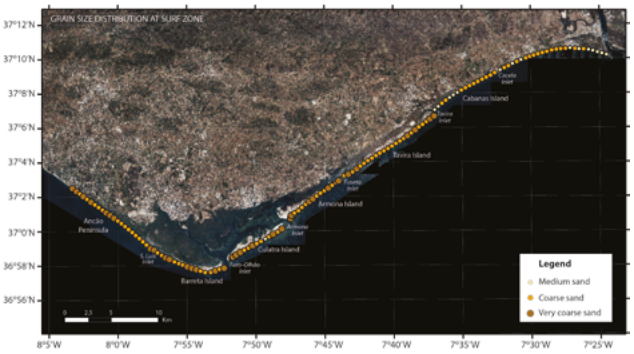

Figure 4. General trend of grain-size distribution at the surf zone between Ancão Peninsula and Guadiana River mouth. Map produced using ArcGIS Pro by Esri. Credits of base map from ArcGIS Pro: Earthstar Geographics.

Figura 4. Tendência geral da distribuição granulométrica na zona de rebentação entre a Península do Ancão e a foz do Rio Guadiana. Mapa produzido usando o software ArcGIS Pro da Esri. Créditos do mapa base do ArcGIS Pro: Earthstar Geographics.

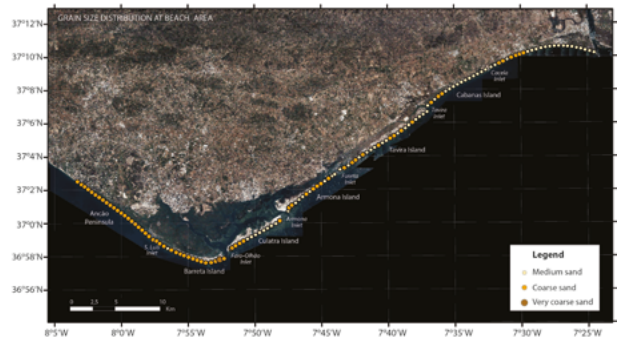

Figure 5. General trend of grain-size distribution at the beach area between Ancão Peninsula and Guadiana River mouth. Map produced using software ArcGIS Pro by Esri. Credits of base map from ArcGIS Pro: Earthstar Geographics.

Figura 5. Tendência geral da distribuição granulométrica na zona de praia entre a Península do Ancão e a foz do Rio Guadiana. Mapa produzido usando o softwaere ArcGIS Pro da Esri. Créditos do mapa base do ArcGIS Pro: Earthstar Geographics.

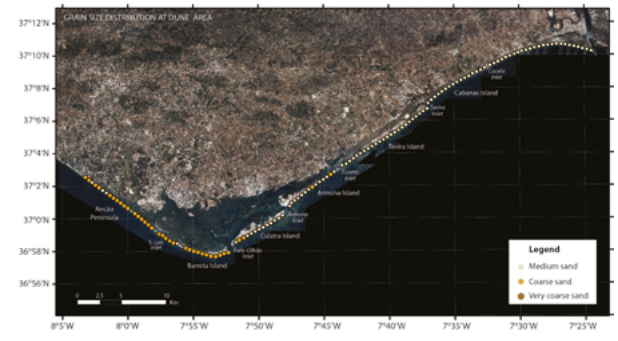

Figure 6. General trend of grain-size distribution at the dune area between Ancão Peninsula and Guadiana River mouth. Map produced using software ArcGIS Pro by Esri. Credits of base map from ArcGIS Pro: Earthstar Geographics.

Figura 6. Tendência geral da distribuição granulométrica na zona dunar entre a Península do Ancão e a foz do Rio Guadiana. Mapa produzido usando o software ArcGIS Pro da Esri. Créditos do mapa base do ArcGIS Pro: Earthstar Geographics.

5. Discussion

The western area is directly exposed to the dominant wave conditions (W-SW), more energetic, which explains the generally coarser sediments observed in this sector. This area is largely sourced by sediments derived from cliff erosion, between Garrão and Quarteira (Andrade, 1990), that are incorporated in the littoral drift and redistributed eastward along the coast. The overwash events in this high-energy western sector (Matias *et al*., 2009) also explain the coarser grain size patterns in the dune environment. Immediately eastwards, in the vicinity of Sta. Maria's Cape, sediment pattern is similar to the observed westwards of the cape, as it is exposed to energetic wave regimes and exposed to similar sediment sources.

In the beach environment, coarse sand dominates in the western sector. In contrast, medium sand extends at the eastern side, apart from some small segments where the appearance of very coarse sand is possibly related to recent artificial nourishment activities, following the practice of shore protection and restoration used in the last decades (Pinto *et al.*, 2018).

The extensive sandy shore developed, during the last decades, from the Cacela Peninsula to the Guadiana River mouth (Lira *et al*., 2016; Nave and Rebêlo, 2021), is characterized by a well-sorted medium sand eastward of Altura village (Figura 5). The Vila Real de Santo António jetty, whose structure prevents littoral drift transport further east, is responsible for the massive sand accumulation, characterized as medium size, on average.

The continental shelf segment between Manta Rota and Guadiana River mouth is under the influence of discharges from the Guadiana River however, only sandy sediments settle mainly in proximal areas of the inner shelf while fine sediments are transported, in suspension, to more distal areas (Gonzalez et al., 2004). According to the work of Rosa et al. (2013), the Guadiana River discharge constitutes the main sediment source at the eastward stretch, being detectable up to the proximity of Manta Rota, as it is shown by the littoral deposits dominated by quartz sands, transported by coastal drift.

6. Conclusions

Preliminary analysis of grain-size data from the dune, beach, and surf zone systems from the Ancão Peninsula to the Guadiana River mouth shows that sediment distribution is controlled mainly by prevailing coastal dynamics (such as waves, currents, and wind) but also by the type and proximity to the sediment sources.

Under the direct influence of the dominant WSW swell, the cliff erosion processes, between Garrão and Quarteira (western sector), provide the coarser sediments which, as a result of the littoral drift, are redistributed along the eastern stretches of the Algarve coast. The overwash events in this dynamic sector also explain the coarser grain size patterns in the dune environment. Sediment pattern eastwards, in the vicinity of Cape Sta. Maria is similar to the observed westwards of the cape, as it is exposed to energetic wave regimes and reveals similar sediment sources.

In the beach environment of the central part of the barrier islands, coarse sand dominates in the western sector. In contrast, medium sand extends at the eastern side, except at some small segments where the appearance of very coarse sand might be explained by recent artificial nourishment activities.

The sand distribution at the dune area where medium sand dominates eastwards of Cape Santa Maria and coarse sand westwards of it, is also related to the more energetic environmental conditions at the western flank, where, besides the wind force, overwash events explain the dominance of coarser particles at the dune environment.

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